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Shah, Nitesh, N.

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1151 E Herman Road
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14. ABSTRACT
We identified several technology transition possibilities: See-Through-The-Wall radar system; a passive approach used in conjunction with the Advanced Tactical Targeting Technology program; sea clutter and Terrain Scatter Interference situations; enhancing Synthetic Aperture Radar systems; and a more speculative application: a reconfigurable array of low-cost, low-resolution transceivers mounted either on unmanned aerial vehicles or carried in soldier backpacks, the combination of the low-capability transceivers together producing a high-resolution result. We collected and provided data to the five university teams. A 35 Ghz radar system with a transceiver placed on a sled on a 10 m linear rail and a receiver held stationary were use to measure corner reflectors and a pickup truck, either in an open area or obscured by desert brush. We held numerous teleconferences with the universities. We hosted site visits by three teams, we made two visits to the experimental facilities of a fourth team, and we interacted with the fifth team at program meetings.

15. SUBJECT TERMS
time reversed waveforms

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Raytheon Company – Missile Systems

14 October 2005

Progress Report/Final Report

15 April 2004 - 14 October 2005

Radar Test Bed For The Evaluation Of Time Reversal Methods

Principal Investigator: Dr. Nitesh N. Shah

Sponsored By:

Dr. Carey Schwartz/DARPA DSO

Program Manager: Dr. Arje Nachman/AFOSR

Issued by AFOSR under Contract # FA9550-04-C-0045

Prepared By:

Raytheon Company - Missile Systems

P.O. Box 11337

Tucson, AZ 85734

Radar Test Bed For The Evaluation Of Time Reversal Methods
Contract # FA9550-04-C-0045
Final Report
14 October 2005

(2) Objectives

There have been no changes to the objectives of the research effort.

(3) Status of Effort

Raytheon Company – Missile Systems (RMS) has been tasked with three objectives: (i) seek paths for technology transfer; (ii) collect and provide data to universities under contract on this program; and (iii) assist universities under contract on this program in developing and executing a Phase I experimental demonstration.

During the period 14 April 2004 through 31 August 2004, we were active in objective (i); we developed a plan for objective (ii); and we held preliminary discussions with universities in relation to objective (iii). During the period 1 September 2004 through 14 October 2005, we have completed all three objectives. We believe we have completed the contract on budget and on schedule. There will be no additional activity on this contract from 31 August 2005 through the official period of performance end date of 14 October 2005.

(4) Accomplishments/New Findings

Technology Transfer Paths

We have been actively seeking paths for technology transfer, with respect to Time Reversal Methods (TRM) applied to radar signals. The ultimate goal of this program is to enable radar-based high-resolution detection of possible targets in environments exhibiting significant multipath scattering (e.g., tanks under trees), a case where conventional radar techniques are able to detect possible targets at resolutions too low to allow credible identification – this is to be accomplished by using multipath scattering to actually enhance the target signal, rather than by attempting to directly mitigate the clutter.

During the period 14 April 2004 through 31 August 2004, we identified one possible transition opportunity that is currently an Advanced Technology Demonstration program at RMS, the See Through The Wall (STTW) radar system (part of a broader class of urban combat radars). We also contacted Raytheon Company – Integrated Defense Systems (IDS) in regard to the possibility of using TRM in radar systems that must contend with sea clutter. This approach is partly based on recent work by Dr. Simon Haykin that shows sea clutter can be modeled as deterministic chaos, rather than a stochastic process, and sea clutter may be amenable to “look-ahead” predictions made using a historical time series. We have also broached a more speculative application, a reconfigurable array of low-cost, low-resolution transceivers mounted either on unmanned aerial vehicles or carried in soldier backpacks, the combination of the low-capability transceivers together producing a high-resolution result.

During the period 1 September 2004 through 14 October 2005, we extended our discussions for possible transition paths to encompass the RMS STTW system, sea clutter environments, a passive approach for use in conjunction with the RMS Advanced Tactical Targeting Technology (AT^3) program, Terrain Scatter Interference (TSI) situations, and enhancing SAR systems (for example gaining useful information from ghosting due to multipath scattering). From Duke University, Larry Carin is interested in the sea clutter and STTW applications, and Jeffrey Krolik is interested in the TSI application. The sea clutter and TSI applications are really aspects of the same underlying approach.

Data Collection

We have collected and provided data to universities, assisting them in validating their modeling and simulation efforts. One important issue has been that of satisfying ITAR requirements, since not all participating university researchers are classified as U.S. persons. With input from Dr. Schwartz, we have been able to document that the data collection methodology and resultant data constitute a form of basic research, a case that does not fall within the purview of ITAR.

We carried out a data collection effort in November and December 2004. The data was posted to the TRM program website. Part of the test plan was driven by specific requests from the UC Irvine / UCDavis team's Hongkai Zhao, Knut Solna and Albert Fannjiang, Northeastern University's Tony Devaney, and Arye Nehorai from the University of Illinois at Chicago. Complete details of the data collection were previously submitted on 6 June 2005 in the informal technical report *Raytheon: MTRM Phase I Data Collection (849 Test Range)*, as well as posted with the data on the TRM program website.

A Ka-Band radar system located in the Building 849 Roof-House test facility was used to collect data on the following targets:

Set A

Clutter (clear area at 428m)

1 Corner Reflector (20 dBsm, clear area at 428m)

5 Corner Reflector Array (clear area at 428m)

F-150 Truck (clear area at 428m)

Set B

Clutter (obscured area at 395m)

1 Corner Reflector (20 dBsm) at 395m (obscured area)

1 Corner Reflector (20 dBsm) at 395m (next to obscured area)

5 Corner Reflector Array (clear area at 390m)

F-150 Truck at 395m (obscured area)

F-150 moving five feet, then standing for 15 seconds (east to west)

The 5 Corner Reflector Array configuration is shown in Figure 1. A single corner reflector and the test object are shown in Figures 2 and 3.

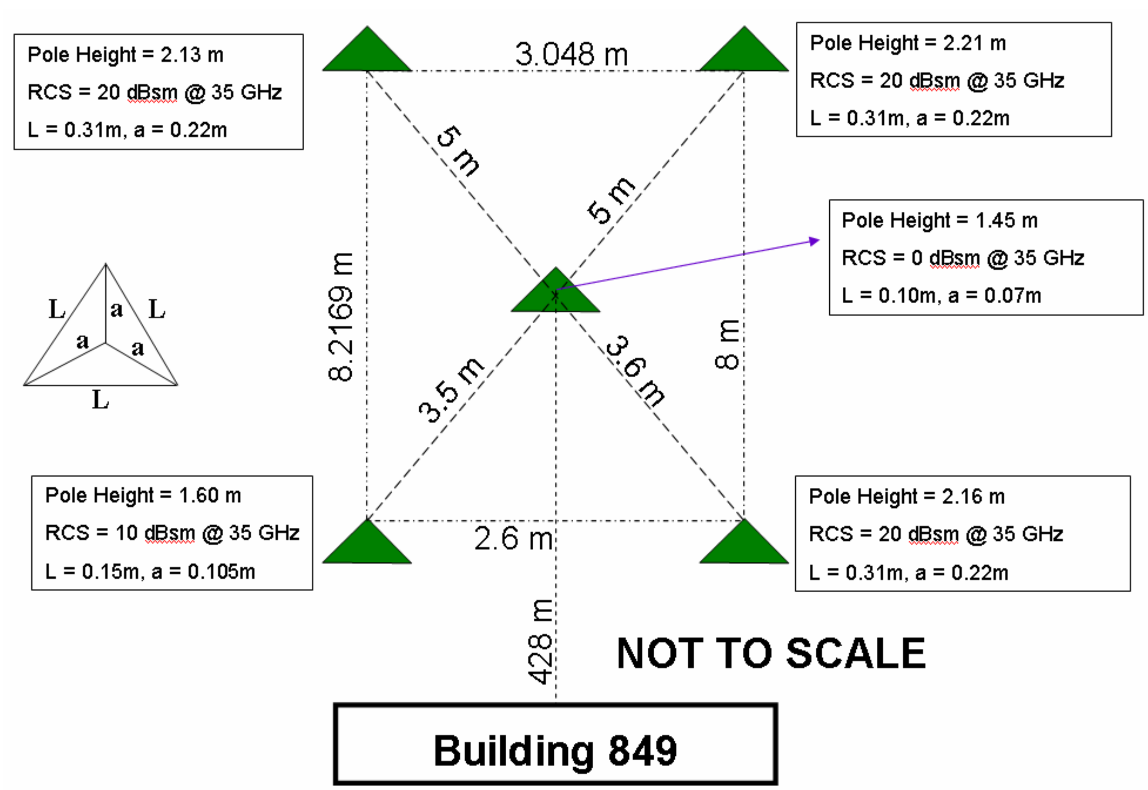

Figure 1. 5 Corner Reflector Test Configuration

Figure 2. Corner Reflector.

Figure 3. Test Object: Ford F-150 Pickup Truck.

The Building 849 Roof-House test facility houses lab space as well as a linear rail (Figure 4) located on the roof. The lab space contains electronics (Figure 5) connected via cabling to the linear rail. The linear rail measures 10 m in length, and the rail sled is moved with a stepper motor having resolution 1.6º / step.

Figure 4. Linear Rail with test sled.

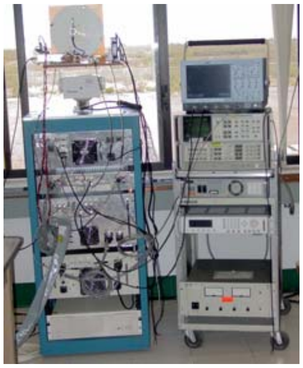

Figure 5. Roof-House electronics.

The radar system operates at a carrier frequency of 35.5 GHz with 1 GHz of bandwidth (transmit: 34.8 – 35.8 GHz, receive: 32.56 – 33.56 GHz). The final IF is 210 MHz with a 100 MHz bandwidth. The waveform is a linear chirp. On the roof, one receiver is fixed in place near the midpoint of the rail. A transceiver is placed on the sled. Thus the system effectively has one transmitter and two receivers. The transmit power is 28.5 dbM, CW. During the data collection campaign, the following parameters were used:

Data Collection Parameters

PRF: 8 Hz

Sled speed: ~ 0.06 m/sec

Time to traverse rail: ~ 170 sec

Approximately 1360 samples along length of rail

Data taken during calm wind conditions

File size: ~ 1360 x 512 downrange points

Grazing Angle: 1°

Squint Angle: 90°

In Figure 6 we show, schematically, the measured patch. In Figures 7 and 8 we show SAR processed images of the test object and the 5 corner reflector array.

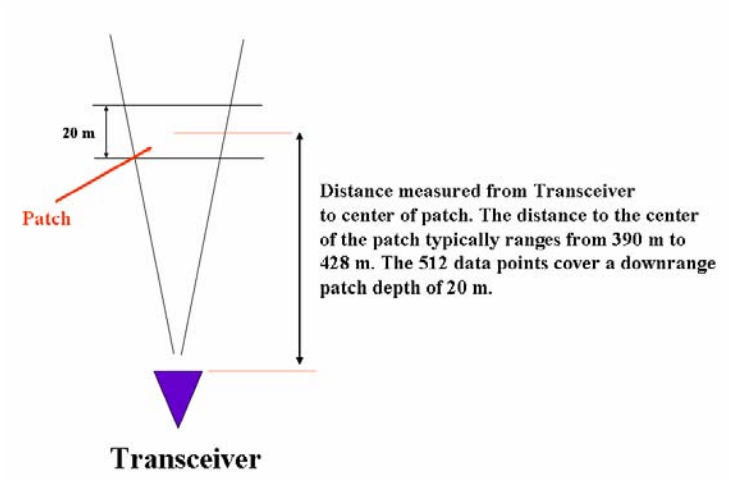

Figure 6. Schematic of measured patch.

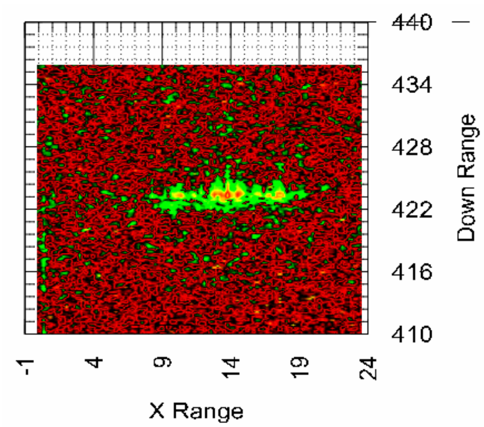

Figure 7. SAR image of Ford F-150 Pickup Truck in a clear area.

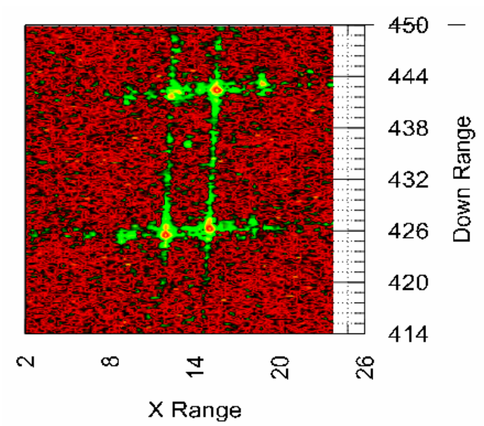

Figure 8. SAR image of 5 corner reflector array in a clear area.

University Support

During the period 14 April 2004 through 31 August 2004, we held several teleconferences with Larry Carin, Tony Devaney, José Moura (Carnegie Mellon University), and Knut Solna (University of California at Irvine). We hosted a site visit by Tony Devaney in May 2004.

During the period 1 September 2004 through 14 October 2005, we hosted a site visit by the UC Irvine / UC Davis team in September 2004, and we made visits to the Carnegie Mellon facilities in November 2004 and December 2004. We hosted a site visit by Larry Carin in March 2005. During 2005, we have had monthly teleconferences with Carnegie Mellon’s Dan Stancil and graduate student Ahmet Cepni. We believe these interactions have been helpful to both RMS and the various university researchers.

(5) Personnel Supported

During the period 14 April 2004 through 31 August 2004, RMS supported four professional people on this contract. Dr. Nitesh Shah, the PI, was engaged in interfacing with Dr. Schwartz, working within RMS to identify transition paths, contacting university researchers, setting up teleconferences and site visits (and handling the associated requirements such as ITAR, non-disclosure agreements, etc.) and coordinating efforts of the other RMS professional people. Mr. Wesley Dwelly (Senior Principal Engineer with Honors; current and future radar systems) and Mr. Alphonso Samuel (Senior Principal Engineer; algorithms) were instrumental in bringing to RMS an understanding of the key concepts of TRM, working with programs to identify transition possibilities, and on broadly defining the baseline test plan. Mr. Johann Schleiss (Senior Engineer; integration and test) worked out details of the test plan. Mr. Dwelly, Mr. Samuel and Mr. Schleiss supported Dr. Shah in teleconferences with university researchers and in hosting site visits by university researchers.

During the period 1 1 September 2004 through 14 October 2005, RMS supported several professional people on this contract. Dr. Nitesh Shah, the PI, has been engaged in interfacing with Dr. Schwartz, coordinating the efforts of other RMS people, and interfacing with participating university researchers. Mr. Alphonso Samuel (Senior Principal Engineer; algorithms) worked with RMS programs to identify transition possibilities and worked with universities to help define the university experiments, in particular during a site visit to Carnegie Mellon University. Mr. Johann Schleiss (Senior Engineer; integration and test) carried out the RMS test plan, with support from several staff members from the integration and test group.

(6) Publications

During the period 14 April 2004 through 31 August 2004, there have been no submitted and/or accepted peer-reviewed publications. During the period 1 September 2004 through 14 October 2005, there have been no submitted and/or accepted peer-reviewed publications.

(7) Interactions/Transitions

(7a) Participation/presentation at meetings, conferences, seminars etc.

During the period 14 April 2004 through 31 August 2004, there has been no participation in meetings, conferences, seminars, etc. During the period 1 September 2004 through 14 October 2005, has been no participation in meetings, conferences, seminars, etc.

(7b) Consultative/advisory functions to other laboratories and agencies.

During the period 14 April 2004 through 31 August 2004, no consultative/advisory services have been provided. However, we have made Dr. Dennis Healy (DARPA/MTO) aware of our involvement in the TRM program, and of the possibility of synergistic overlap between the TRM program and DARPA/MTO's Analog-to-Information initiative. During the period 1 September 2004 through 14 October 2005, no consultative/advisory services have been provided.

(7c) Transitions.

During the period 14 April 2004 through 31 August 2004, no transitions have occurred. During the period 1 September 2004 through 14 October 2005, no transitions have occurred. However the RMS STTW and AT^3 programs have been made aware of the TRM technology, and Dr. Tom Wood, a program Chief Engineer at RMS' sister company IDS, has started discussions with us on the possibility of using TRM to improve detection in a sea clutter environment.

(8) New discoveries, inventions, or patent disclosures.

During the period 14 April 2004 through 31 August 2004, there have been no new discoveries, inventions, or patent disclosures. During the period 1 September 2004 through 14 October 2005, there have been no new discoveries, inventions, or patent disclosures.

(9) Honors/Awards.

During the period 14 April 2004 through 31 August 2004, there have been no honors or awards. During the period 1 September 2004 through 14 October 2005, there have been no honors or awards. Dr. Nitesh Shah, the PI, received a promotion to Principal Engineer.

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